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Validation of the Wind Erosion Equation (WEQ) for Discrete Periods

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Introduction

In the United States, the USDA Natural Resources Conservation Service (NRCS) is the primary agency charged with the task of reducing wind erosion associated with production agriculture. The NRCS has used the Wind Erosion Equation (WEQ) (Woodruff and Siddoway, 1965) to assess the effects of field management on the potential for wind erosion for the last two and a half decades. The WEQ uses inputs of soil erodibility, ridge roughness, locally calibrated climatic factors, field length, and vegetative cover to predict the potential annual wind erosion for a given field and set of management variables. By using this model, the NRCS is able to direct producers toward crop management systems that effectively reduce erosion.

Wind erosion modeling efforts by the USDA Agricultural Research Service (ARS) over the last decade have necessitated the collection of several large bodies of wind erosion and weather data from many diverse locations in the United States. This effort has been facilitated by the development of technology and equipment that have enabled the measurement of wind erosion losses on storm event basis (Fryrear, 1986; Stout and Zobeck, 1996). The availability of field measurements has improved the description of erosion losses across a field (Stout, 1990) and also permits the validation of wind erosion models. We tested WEQ against much of the aforementioned body of data in order to determine the accuracy of its predictions.

The Global Change and Terrestrial Ecosystems Soil Erosion Network (GCTE-SEN) has recently conducted a model validation exercise for water erosion models (See September - October 1996, J. Soil & Water Conserv.). Several models also are available to estimate wind erosion losses, but few studies have compared the output from these models with field-measured data. In this study, as part of a GCTE-SEN project, we evaluate how well predictions of erosion made with a commonly used model compare with data collected from eroding fields. We also investigate appropriate factors that may be changed to calibrate WEQ for local climate and soil conditions.

Methods

Seven sites from six states across the United States were chosen to validate WEQ. The site locations, years of comparisons, soils classification, soil erodibility index (I), and climate factor (C') are presented in Table 1. The sites were described, instrumented, and the erosion data collected by USDA-ARS and USDA-NRCS personnel. All the sites were a 100 m radius circular field (~ 2.5 ha) outfitted with a weather station and 13 erosion sampling stations. Weather data collected included rainfall, wind speed, and wind direction at one minute intervals. Soil surface condition data including ridge height, random roughness, crusting, percent erodible fraction in the absence of crusting, and standing and flat plant residues were collected several times a season.

Soil saltation and suspension loads at each of the 13 field locations were estimated by taking the weight of sediment collected in individual samplers at those locations and calculating the transport load (Fryrear et al., 1998). Creep load was estimated for each of the 13 locations in a similar manner based upon transported soil weights collected at 4 locations in the field. Field

Table 1. Test site locations, soils and climate factors.

Location	Years of Comparison	Soil Classification	I	C
Big Spring, TX	1989, 90, 93, 94, 95, 96, 97	Amarillo fine sandy loam	86	60
Kennett, MO	1993, 94	Farrenburg fine sandy loam Malden loamy fine sand	86 134	10
Eads, CO	1991	Wiley silt loam	56	90
Elkhart, KS	1992	Dalhart fine sandy loam	86	70
Sidney, NE	1990	Alliance silt loam	56	50
Prosser, WA	1992	Shano silt loam	56	55
Mabton,WA	1991	Quincy loamy fine sand	134	50

soil loss for each event was calculated using soil transport estimates from selected locations across the field. Since all these field erosion observations are calculated estimates based upon actual measured observations, we will refer to the erosion data as observed estimates.

A spreadsheet version of WEQ developed by Mike Sporcic and Leigh Nelson of the USDA-NRCS in Spokane WA was used to evaluate the accuracy of WEQ. This spreadsheet version requires user input of field identification and width, tillage direction, field orientation, field length to width ratio. Input values for C' value (climatic factor), soil I (erodibility), and soil wind erodibility group were taken from the appropriate sections of Part 502 National Agronomy Handbook (USDA-SCS, 1978). Internal menus allow selection of local average wind data tables for the specified location, crop, and field management. The crop and field management is entered by user specified date, allowing the spreadsheet to calculate ridge height and spacing, standing biomass, standing and flat residue, and random roughness for the period extending from that entry to the next. The model predicts the potential erosion for each of these management periods and sums them to obtain average annual wind erosion.

We entered previous crop and tillage management information as was presented in the field notes and records. In order to obtain a better fit of the menu choices and internal calculations with field observations, we occasionally adjusted tillage operations to create residue and roughness effects similar to those observed and sparsely planted crops during periods where photographs indicated that weeds were developing in the fields. Management dates were chosen to coincide with the dates of field sampler installation and removal so that the WEQ predictions of erosion could be summed to coincide with the period of actual field data collection.

Results and Discussion

A summary of WEQ simulation results and comparisons with observed estimates is presented in Table 2. Averaged across all sites and years of comparison, WEQ predicted only 53.3% of the observed estimated erosion. WEQ only predicted 37.5 % of the observed estimated erosion at Big Spring for all 7 years of comparisons. If we remove the comparisons for 1996, a year with much lower than average winds, WEQ only predicted 22.6% of the observed estimated erosion. Similar results were noted for most of the other sites with the exception of relatively good agreement between WEQ predictions and observed estimated erosion for Eads, CO and Elkhart, KS both of which are located near the area where WEQ was developed. Highly variable results were noted between the two years of comparison at Kennett, MO. Dissimilar surface conditions between the two years of comparison are reflected in the differences in WEQ predicted erosion, but the differences in observed estimated erosion between the two years was much greater than in the predicted erosion. On-site wind data indicated that 1993 was much windier than 1994 resulting in observed estimated erosion in 1993 of more than 20 times that noted in 1994.

WEQ uses statistical wind distribution data for input wind parameters and therefore should not be expected to match each year's observed estimated erosion since the magnitude, duration, and direction of erosive winds vary from year to year. Woodruff and Siddoway (1965) state that wind speeds are normally distributed. Analysis of 5 minute average and daily average wind speed for Big Spring, TX indicates that this is not the case. Winds of erosive velocity typically occur only a few hours out of the day and a few days per month. Long periods of sub-erosive velocity winds separate the extreme events. Additionally, detailed saltation activity data for Big Spring, TX would indicate that daily average wind speed is a very poor predictor of wind erosion activity. It was not uncommon to note three orders of magnitude higher saltation activity on a day with a lower daily average wind speed than another day within the same week.

Attempts to create simulation conditions that would allow WEQ to more closely predict the erosion for 1989 and 1990 at Big Spring, TX, two average years, yielded interesting results. We at first assumed that the wind velocity parameter in the C' factor was perhaps underestimated for this location. C' values were varied from 60 to 150, 2.5 times the given value for the location and the maximum value indicated for any location, and yet WEQ only predicted 57.3% and 60.2% of the observed estimated erosion for 1989 and 1990 respectively. The C' factor had to be increased to 222, a value nearly 4 times that published for the site, in order for the predicted erosion to be 95.6% and 104.4% of the observed estimated erosion for 1989 and 1990, respectively. Woodruff and Armbrust (1968) recommend use of a monthly C' that improves the accuracy of WEQ simulations. While monthly values for the erosive season at Big Spring are larger than the annual value, they are still too low to allow good agreement between WEQ predictions and observed estimates in the two years investigated. Further, there is no provision for varying the C' value within years of simulation in this version of WEQ so management periods would have to be separated by months, individual annual simulations run with C' values for each month, and the appropriate soil loss figures would have to be summed across 12 simulations for a single year's prediction. This problem could, however be solved by modification of the spreadsheet and a table of monthly C' values by location.

Table 2. Summary of WEQ predicted erosion, observed estimated erosion, and comparison.

Location	Year	Comparison Period	WEQ Predicted (T/ac)	Observed Estimates (T/ac)	WEQ/Observed (%)
Big Spring, TX	1989	01/12/89 - 05/03/89	20.02	96.11	20.8
Big Spring, TX	1990	01/05/90 - 05/04/90	20.79	93.52	22.2
Big Spring, TX	1993	03/16/93 - 06/01/93	14.16	128.42	11.0
Big Spring, TX	1994	01/06/94 - 05/18/94	20.81	76.57	27.2
Big Spring, TX	1995	01/11/95 - 05/15/95	21.75	117.31	18.5
Big Spring, TX	1996	01/12/96 - 05/16/96	22.63	17.80	127.1
Big Spring, TX	1997	01/23/97 - 05/23/97	21.67	60.82	35.6
Eads, CO	1991	10/30/90 - 05/07/91	10.54	10.84	97.2
Elkhart, KS	1992	01/01/92 - 10/15/92	87.95	69.16	127.2
Kennett, MO	1993	12/02/92 - 06/17/93	6.83	61.26	11.1
Kennett, MO	1994	11/18/93 - 05/05/94	3.98	2.86	139.4
Mabton, WA	1991	12/13/90 - 04/28/91	2.68	16.42	16.3
Prosser, WA	1992	06/10/92 - 06/15/93	0.74	1.43	51.8
Sidney, NE	1990	10/24/89 - 04/24/90	0.8	1.96	40.7

While holding the value for C' at 150, the soil erodibility index, I, was increased to 134 to provide a prediction of 98.4% and 105% of the observed estimate for 1989 and 1990 respectively. If we returned the C' value to 60 and increased the soil erodibility index, I, to the maximum value of 310, WEQ predicted 101.4% and 108.1% of the observed estimates for the respective years. Although reasonably good fits can be obtained by varying the I value alone, it would be difficult to predict erosion for a soil more erodible than a fine sandy loam and many agricultural soils in this area are loamy fine sands and fine sands. It should be pointed out, however that the soil erodibility index, I, values for WEQ are based upon the percentage of soil aggregates in the upper inch of soil larger than 0.84 mm. While this value may be appropriate for freshly tilled soils, rainfall often results in the disintegration of aggregates, crusting of the soil, and creation of a surface mantle of sandy abrader material. This sandy abrader is usually the first material to move during a wind event and thus the apparent texture of the surface soil would approximate the soil for which a soil erodibility index, I, of 310 would be appropriate. This adjustment of soil surface conditions would also be easier to implement in areas where detailed information on actual wind erosion rates were not available to allow C' adjustment for local model calibration.

Conclusions

WEQ tended to underestimate the observed estimated erosion in most cases but the performance did improve with local calibration for the Big Spring, Texas location. Increasing the annual input value of C' to nearly four times the published value did allow close agreement between predicted and observed erosion as did increasing the value of I to the upper limit and combinations of increased C' and I input values. The use of increased values of I could be explained by the texture of the surface mantle of fine sand resulting from the rain induced disintegration of soil aggregates and points to the importance of soil surface conditions in controlling wind erosion and the necessity of careful characterization of these soil surface conditions when running predictive wind erosion models.

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